International Journal of Agricultural Science and Research (IJASR)
ISSN(P): 2250–0057; ISSN(E): 2321–0087
Vol. 9, Issue 6, Dec 2019, 51–60

DRAFT MEASUREMENT OF FIVE TYNE DUCK FOOT CULTIVATOR

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ABSTRACT

Draft requirement of five tyne duck foot cultivator was studied on different soil moisture content, depth of operation and forward speed of tractor using a specially designed three point hitch dynamometer. The designed dynamometer can be matched with the tractors having category II or III hitch systems. The data acquisition system adopted for the dynamometer had NI WSN-3214 Strain Nodes, NI 9792 WSN real-time Gateway and NI LAB View 2013 software. A data logger program was developed for the three point hitch dynamometer. The investigation was carried out at that three levels soil moisture content (10–13%, 14–16% and 17–20%), at three different depth of operation (15, 20 and 25 mm) and three level of forward speed of tractor (3, 5 and 7 km h^{-1}). The designed dynamometer was performed well in all the levels of the experiment. From the results, it was observed that draft force required for five tyne duck foot cultivator was increased with increase in soil moisture content whereas it was increased with increased in depth of operation and forward speed of tractor.

KEYWORDS: Three point hitch dynamometer, Draft, Data Acquisition & Five Yne Duck Foot Cultivator

Received: Oct 06, 2019; **Accepted:** Oct 26, 2019; **Published:** Nov 11, 2019; **Paper Id.:** IJASRDEC20197

1. INTRODUCTION

In India, several farm implements are commercially available for different field operations, such as ploughing, sowing, weeding and harvesting. Measurement of draft for particular implement in the particular soil condition is necessary for selection of implements and power source. Perfect *et al.* (1997) measured the fuel consumption in respect of draft force. It was concluded that 42.8 % energy saving was achieved with variable tillage, by fuel consumption of 28.4% to prior methods (Gorucu *et al.* 2001). To use the tillage machinery efficiently, data on draft of tillage tools in various soil conditions were much useful (Alimardani *et al.* 2006).

Tractor operated five tyne duck foot cultivator is one of the recently popularized implements being used by the farmers for primary tillage operation to plough the field. There is a lack of detailed study on the draft requirement of the tractor operated five tyne duck foot cultivator which may results in low efficiency with more energy requirement.

Several researchers have developed different models of three point hitch dynamometers for draft of tillage implements. Barker *et al.* (1981) designed the dynamometer which measures resultant forces by load cells mounted in two sub-frames. It was designed with quick attaching coupler for inter changeability of category III implement.

Bandy *et al.* (1986) developed a dynamometer with most using mounted strain gauge load cells for measuring draft on tractors. It was concluded that load cell dynamometers of two types were available. The sub-frame assembly between tractor and mounted implement was most commonly used. Later were integral systems of load sensing elements between tractor and mounted implement.

Manohar Jesudas (1994) developed a tillage dynamometer for evaluating the performance of deep tillage tool. The behaviour of deep tillage tools under same soil conditions was predicted by using existing models. The experiment was conducted with five levels of share width, *viz.*, 20, 25, 30, 40 & 50 mm and three levels of share length 100, 150 & 200 mm with a share lift angle of 20° and tested at five levels of depth and five levels of speed. The results of the field experiments conveyed that the longitudinal reaction of the most shares at a depth of 35 cm and speed of 1 m/s was varied between 778 kg and 1065 kg. The horizontal reaction versus share length relation favoured the selection of 150 mm long share to ensure minimum draft.

Kheriralla *et al.* (2003) developed and calibrated a three point hitch dynamometer which measures the horizontal and vertical forces existing at the three point linkage of the Massey Ferguson 3060 tractor for mounted implements having hitch category I and II. The dynamometer has inverted (U frame) assembly consist of three extended octagonal ring transducers. The operating range for horizontal and vertical force of transducer was designed from 25 to 10 kN, though the three point hitch dynamometer was designed for 50 to 20 kN.

Alimardani *et al.* (2008) investigated the draft power requirement for pull type implements. The force between tractor and mounted implement is considered by designer which justifies the needs of a three point hitch dynamometer. In the study, a three point hitch dynamometer having high sensitivity and strength, measuring five force components simultaneously, compensating the temperature changes using the full Wheatstone bridge and adapted to the tractor categories 0 and 1.

Pijuan*et al.* (2012) designed the three point hitch dynamometer, which can be attached to II and III category agricultural tractors to measure the longitudinal, vertical and lateral forces. The data were obtained from six independent links with the corresponding load cells. The developed dynamometer was built with adjustable pin joints that allow for attaching it to a wide range of implements.

Tewari *et al*. (2012) designed and developed the dynamometer for measuring draft of mounted implements which attached to three point linkage. It consists of extension arms (Left and Right), load sensor, inverted T frame and head bar. To measure bending forces on the lower links, three load cells attached in sensing bodies. Prior to field tests, the three point linkage dynamometer was calibrated. Sufficient numbers of field tests were conducted to measure pull force of an implement. To analyse the developed dynamometer degree of accuracy, it was compared to dynamometer readings which is having strain gauges in three links. A variation of ±8 kg was observed during field trials, between developed dynamometer and strain gauge dynamometer.

2. MATERIALS AND METHODS

A commercially available five tyne duck foot cultivator was taken for the draft measurement study (Figure 1). The duck foot cultivator consists of a channel steel rectangular frame, rigid tines and sweeps. Leaf spring steel sweeps in the shape of duck foot are used. The sweeps are fitted fashionably to replace, when worn out. Forged mild steel was used in tynes. This cultivator was mostly used in hard soils for primary tillage operation.

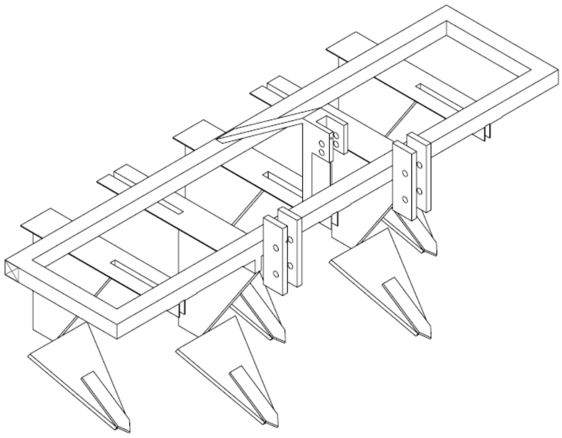

Figure 1: Five Tyne Duck Foot Cultivator.

The specifications of the five tyne duck foot cultivator are given in table 1.

Table 1: Specification Five Tyne Duck Foot Cultivator

Sl. No.	Description	Dimension
1	Number of tynes	5
2	Main frame, mm	2290 × 550
3	Working width, mm	300
4	Weight, kg	280
5	Power requirement, hp	35–55

2.1 Draft Measurement System

A specially designed three point hitch dynamometer was used for this research (Figure 2). The developed three point hitch dynamometer is a universal system in the manner of using for various categories of implements. The three point hitch dynamometer consisted of tractor end frame, implement end frame, load cells and telemetry data acquisition system.

The dynamometer is a double frame unit. The front side of the tractor end frame is attached to tractor hitch and rear side of implement end frame is attached to the implement. The hitch points of the implement end frame are movable for hitching with implement. The three point hitch dynamometer can be easily connected or disconnected with the tractor and implement. To measure the draft forces of implement, six load cells are used. The three point hitch dynamometer attached with all accessories weighed of 130 kg. The developed three point hitch dynamometer can be attached to category II or III tractors. The design of three-point hitch dynamometer hexagonal pattern and also allows mounting of Power Take-Off (PTO) driven implements without torque sensing.

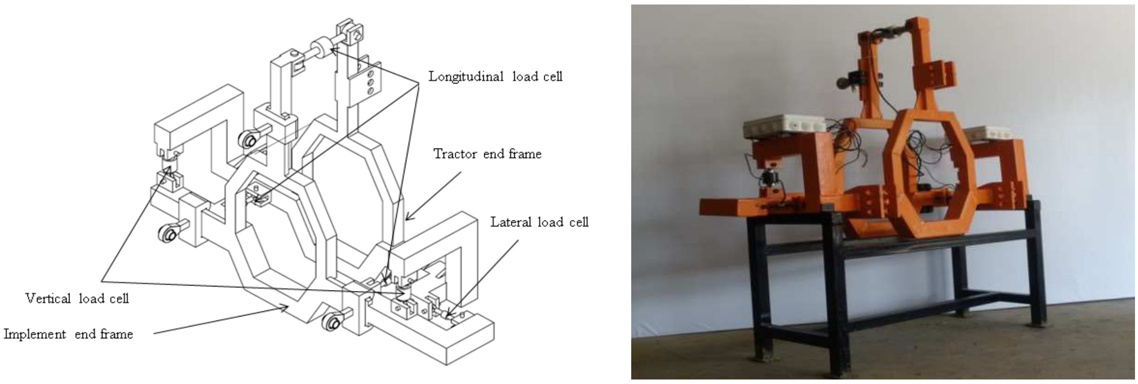

Figure 2: Developed three Point Hitch Dynamometer.

The two lower links and one top link assembly is provided in the rear side of implement end frame and tractor side of the implement frame provided with the load cell mounted unit. The weight of the implement end frame was 60 kg.

The designed three point hitch dynamometer required six cylindrical load cells on three orientations. The six load cells are equally arranged in every directions i.e., three load cells for longitudinal direction, two load cells for vertical direction and single load cell for lateral direction. The load cells have maximum and minimum capacity of 2000 kg and 500 kg. These load cells are connected between tractor end frame and implement end frame with eye rod end bearing.

The six load cells were connected to the Wireless Sensor Network 4-Ch Full Bridge Strain Node, each for connected with three load cell. The NI WSN-3214 Strain Node mounted on top of the three point hitch dynamometer in implement side frame. The data acquisition system consisted of NI WSN-3214 Strain Nodes, NI 9792 WSN real-time Gateway, computer running NI LAB View 2013 software with developed data logger program. This data acquisition system was powered with 12 V, 7 Ah DC battery in remote side of the field. The computer was utilised for running the developed data logger LAB View program.

The flow diagram for three point hitch dynamometer data acquisition system on draft measurement of mounted implement is shown in figure 3.

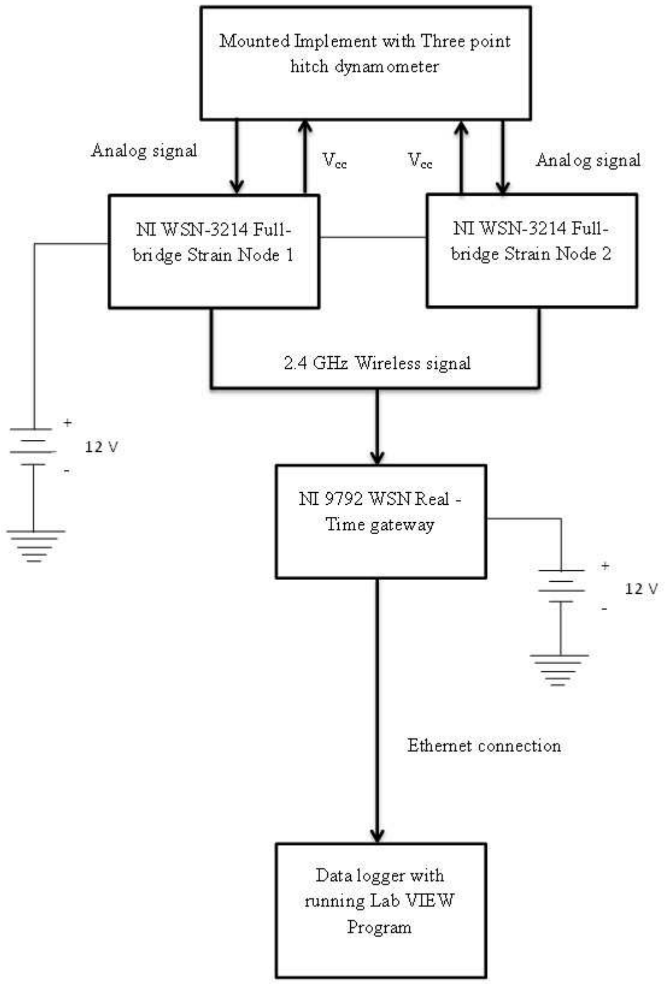

Figure 3 Flow Diagram for three point Hitch Dynamometer Data Acquisition System on Draft Measurement of Mounted Implement.

2.2 Calibration of Load Cell

The calibration of load cells was done with developed Lab VIEW program in order to determine the output quantity on input quantity characteristic. This characteristic of load cell with strain gauges represents dependence of the output voltage of load cell on the load itself. A virtual instrument has been created in Lab VIEW software for measure the output voltage of load cell. To calibrate the load cell, it was attached with an electronic balance and whole unit mounted in chain jack. The known load was applied in chain jack, as increasing manner. The mounted unit loads were verified with electronic weighing balance (kg) and readings from Lab VIEW were noted (mV) down. After the procedure finished, the calibration curves were plotted.

2.3. Force and Moment components of Dynamometer and Five tyne Duck Foot Cultivator

The force and moment components in the Cartesian coordinate system, as shown in Figure 4 were computed from the following equations.

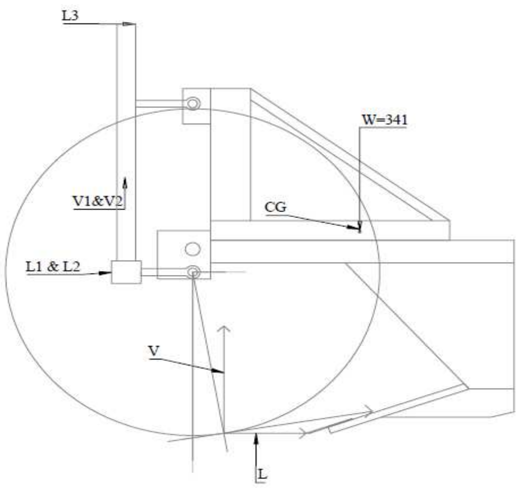

Figure 4: Force and Moment Components of three point Hitch Dynamometer.

Due to small range of lateral force produced by assymetrical implements on three point linkage, it was neglected. Hence, the resultant (RE) derived in a two dimensional system instead of three dimensional system.

Resultant force (RE) as below,

$$L = L1 + L2 + L3$$

$$V = V1 + V2 – W$$

$$W \times Xw + L3 \times M – L \times Y_1 + (V1+V2)*Xv = 0$$

$$RE = \sqrt{[(L^2) + (V^2)}$$

$$W \times Xw + L3 \times M – R \times rr+(V1+V2) \times Xv =0$$

Angle of resultant (θ) in XY plane,

$$\theta = \arctan\left(\frac{V}{L}\right)$$

ΣFx, ΣFy and ΣFz were the force components along the x, y and z axes. L1, L2, L3, V1, V2 and S were the forces on load cells. a, b and h were the position parameters of the load cells, and W was the weight of the sub frame and implement. The resultant force represented in equation was the single force, resolution of horizontal and vertical components on three point linkage, acted at a distance of (a), oriented at an angle of (θ) from the rear axle.

2.4 Field Test

The factors which are affecting draft force and energy for tillage are soil moisture content, soil structure and cone index (Upadhyaya*et al.*, 1984).

Figure 5: Draft Measurement of Duck Foot Cultivator in Field Condition.

The field test of the three point hitch dynamometer on the tractor and implement performance was conducted in Eastern black farm Tamil Nadu Agricultural University, Coimbatore which has clay soil (Figure 5). To measure the soil moisture content, soil samples were collected at 10 points. The soil moisture content was measured on dry basis, for which the soil samples were weighed, oven dried at 105°C for 24 h and weighed again.

The tractor was equipped with data acquisition system and duck foot cultivator. The field tests were conducted to analyse the draft requirement of five tyne duck foot cultivator at variable soil moisture content, i.e., 10–13%, 14–16% and 17–20%, different depth of operation i.e., 15, 20 and 25 cm and forward speed of operation of the implement *viz.*,3, 5 and 7 km h^{-1}.

The data were stored in Lab view programme for analysis on draft requirement of the duck foot cultivator by using the associated data acquisition system. The dynamometer was horizontally adjusted parallel to ground surface, before conducting the experiment. The data acquisition system signal was covering up to a distance range of 30 m.

3. RESULTS AND DISCUSSIONS

Prior to measure the draft of mounted implements by developed three point hitch dynamometer, the load cells which mounted in dynamometer were calibrated and constants derived from calibration procedures were used to obtain the forces in metric units. The horizontal and vertical forces of the duck foot cultivator were measured in the field at different soil

moisture content, depth of operation and speed of travel of the implement. The average horizontal force and average vertical force measured were 405 kg and 68 kg (Figures 6 and 7), whereas the calculated resultant force was 408 kg (Figure 8).

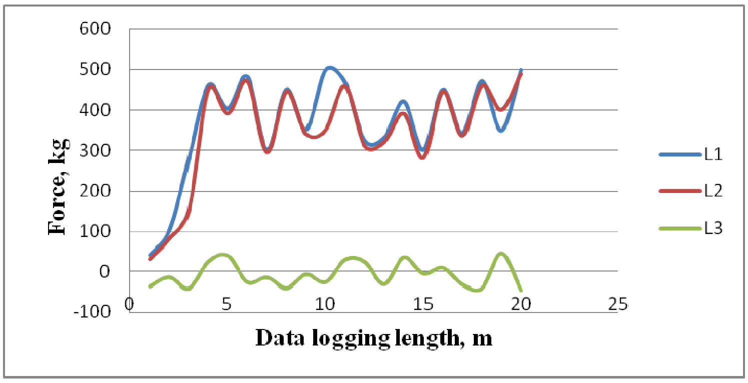

Figure 6: Horizontal Force of Duck Foot Cultivator.

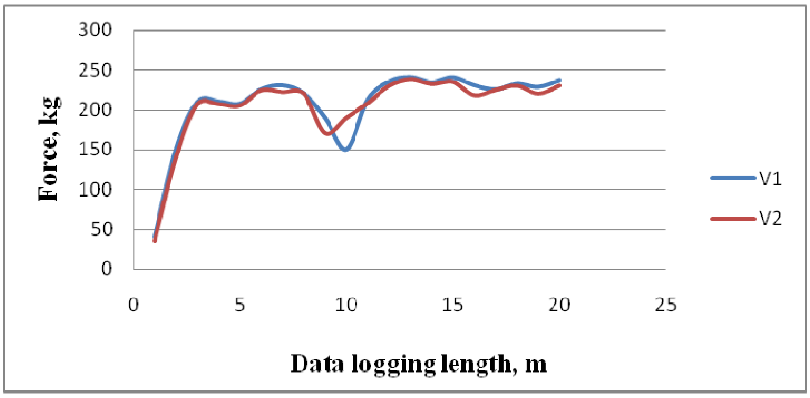

Figure 7: Vertical Force of Duck Foot Cultivator.

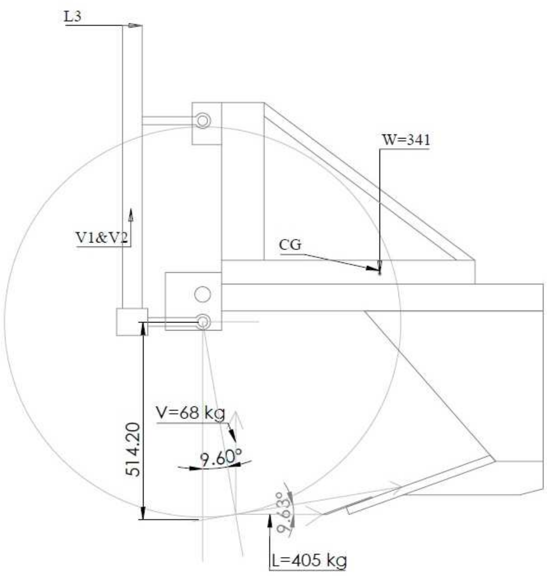

Figure 8: Calculated Resultant Force of Five Tyne Duck Foot Cultivator.

The figures 9 and 10 showed the draft measured in kg at different soil moisture content and at different depth, respectively.

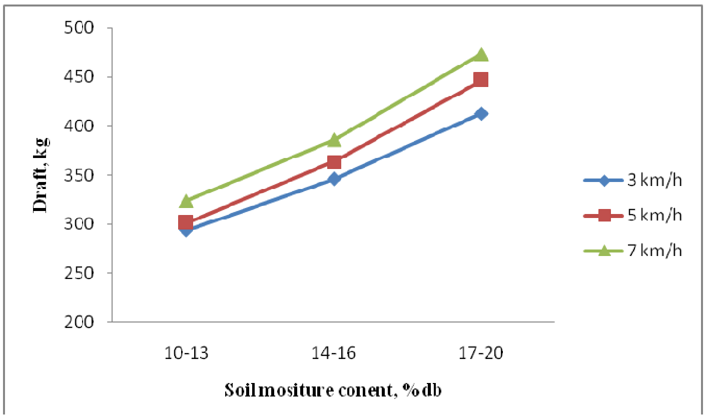

Figure 9: Soil Moisture Content vs Draft.

From the graph, it was observed that the draft was increased with increase in moisture content for all forward speed of operation of the implement. The maximum draft was observed with 17–20% moisture content at 7 km h^{-1}speed.

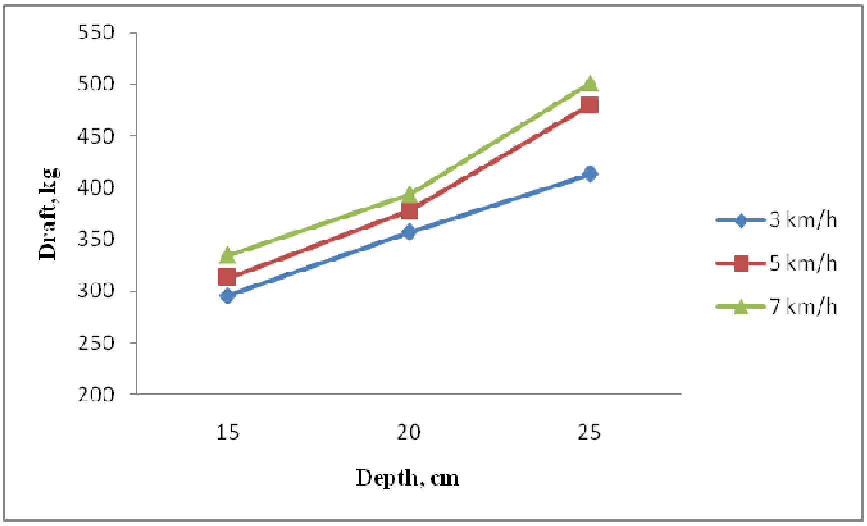

Figure 10: Depth of Operation vs Draft.

It was revealed that the draft was increased with increase in depth of operation of the implement for all forward speed of the tractor, whereas the maximum was observed with 25 cm depth at 7 km h^{-1} speed.

4. CONCLUSIONS

The draft requirement of five tyne duct foot cultivator was measured with newly developed three point hitch dynamometer on different soil moisture content, depth and speed of operation of the implement. The developed dynamometer performed well in all the levels of the experiments. The horizontal and vertical forces measured were 405 kg and 68 kg and calculated resultant force was 408 kg. The draft was increased with increase in moisture content for all forward speed of operation of the implement. The maximum draft was observed with 17–20% moisture content at 7 km h^{-1} speed. The draft was having direct relationship with depth of operation, while increasing depth of operation, the draft of implement was also increased and attained the maximum value at 25 cm depth of 7 km h^{-1} forward speed.

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